Semi-analytic models for galaxy formation

Lecture Galaxy Formation and Evolution

by Else Starkenburg

Contents

- What is semi-analytic modelling about?
- Brief discussion of the three main models
- Seven stages in modelling
  - Cosmology
  - Evolution of the Dark Halos
  - Star Formation & Stellar Populations
  - Feedback and metal evolution
  - Merging
  - Normalization
- What are the main successes and problems of semi-analytic models?
- Is semi-analytical modelling useful?

What is semi-analytic modelling about?

- Following evolution of Galaxies
- Hierarchical clustering
- Use/testing of relevant physical processes

Brief discussion of main three models

- Munich - Kauffmann, White & Guiderdoni (1993)
- Durham - Cole et al. (1994)
- Santa Cruz – Somerville & Primack (1999)
- Main differences:
  - Setting model parameters using normalization
  - Details of the physical processes:
    - Star Formation
    - Gas Cooling
    - Feedback

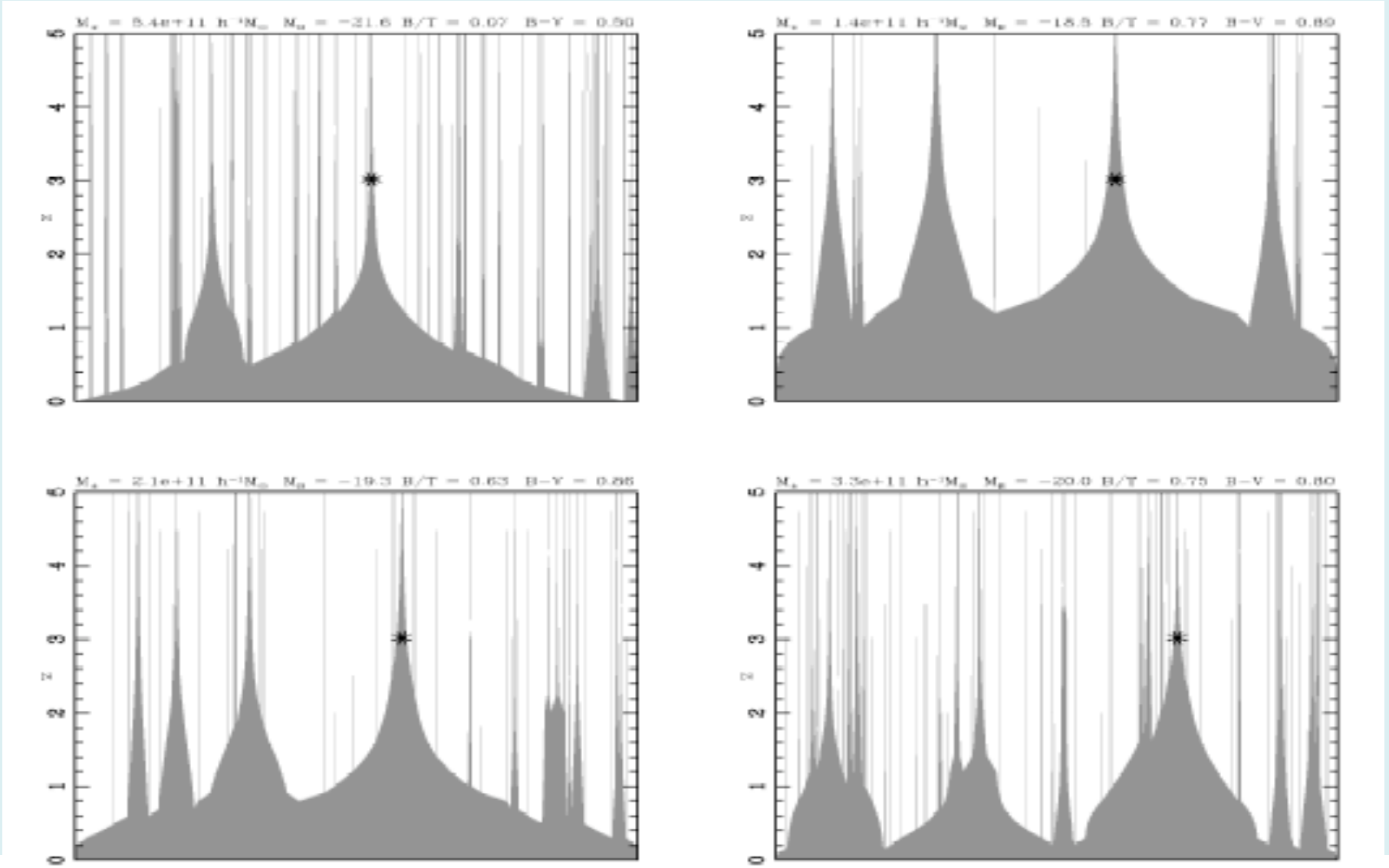
Modelling stages: Cosmology

- Cosmology = starting point of the model
- Important parameters:
  - Ω_m
  - H_0
  - Ω_b / Ω_m
- Recently: Everybody uses ΛCDM
  - Is this a good developement?

Modelling stages: Evolution of Dark Halos

- Press-Schechter formalism
- Spherical collapse model
- Assumptions:
  - The halos and their perturbations are spherical
  - Halo density profiles are SIS
  - Inner density fluctuations have same density profile
- For merging also: Extended Press-Schechter formalism (split of models)
- Recently: Also N-body simulations, slower, but possible due to one cosmology

Modelling stages: Evolution of Dark Halos (2)



Modelling stages: Gas Cooling

- Assumptions
  - Gas is initially shock heated to virial temp. of halo $kT = \mu m_p V_c^2/2 = 35.9\ V_c^2$
  - Gas cools if cooling timescale < characteristic timescale (different for different models)
- But:
  - In reality not all gas goes to hot phase

Modelling stages: Star formation & Stellar Populations

- All three models make assumption: $M^* = M_{cold}/t^*$
  - t^* = constant
  - t^* = power law in V_c
  - t^* = proportional to galaxy dynamical time
- All three models assume different t^*
- All models assume that the IMF of stellar populations is universal although exact form varies
- Metallicity

Modelling stages: Feedback

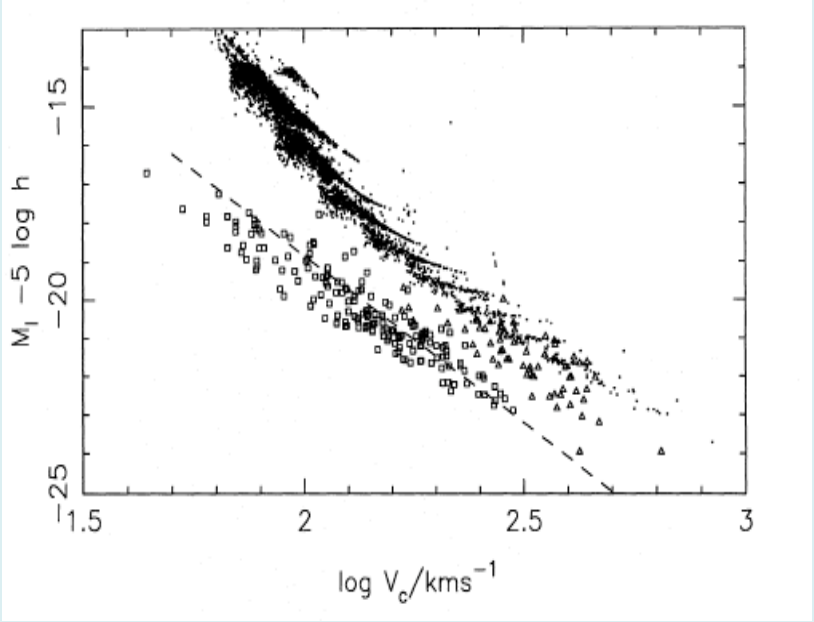
- Assumption: Cold gas is reheated by "feedback"
  - $dM_{reheat}/dt = \varepsilon^0_{SN} (V_c/V_0)^{-\alpha_{reheat}} dM^*/dt$
  - $dM_{reheat}/dt = \varepsilon^0_{SN} E_{SN} \eta_{SN} (dM^*/dt) / v_{esc}^2$
- What is the origin of this feedback?
  - Effects of SN (pushing or heating?)
  - Effects of Super Massive Black Holes
- Where does the reheated gas go?
- Does the gas eventually return to the halo?

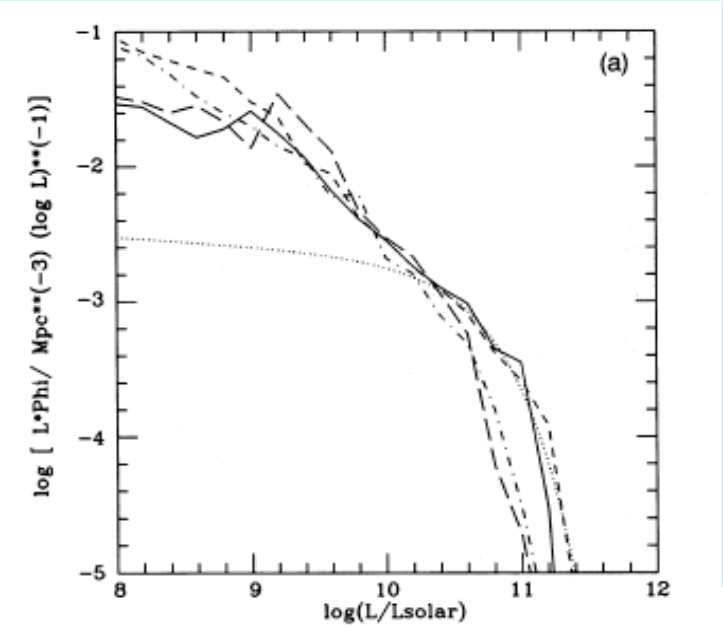
Modelling Stages: Merging

- All models allow merging under assumptions:
  - Hot halo gas is shock heated to new virial temperature
  - Galaxies merge within dynamical friction time (* free parameter)
  - Cold gas in subclumb is attached to center, hot gas to hot gas reservoir
  - Mergers of galaxies with mass ratios small enough form bulges
- But:
  - Hoe long is a dynamical friction time?
  - Do satellites also merge with eachother?
  - Is it true that bulges are formed?

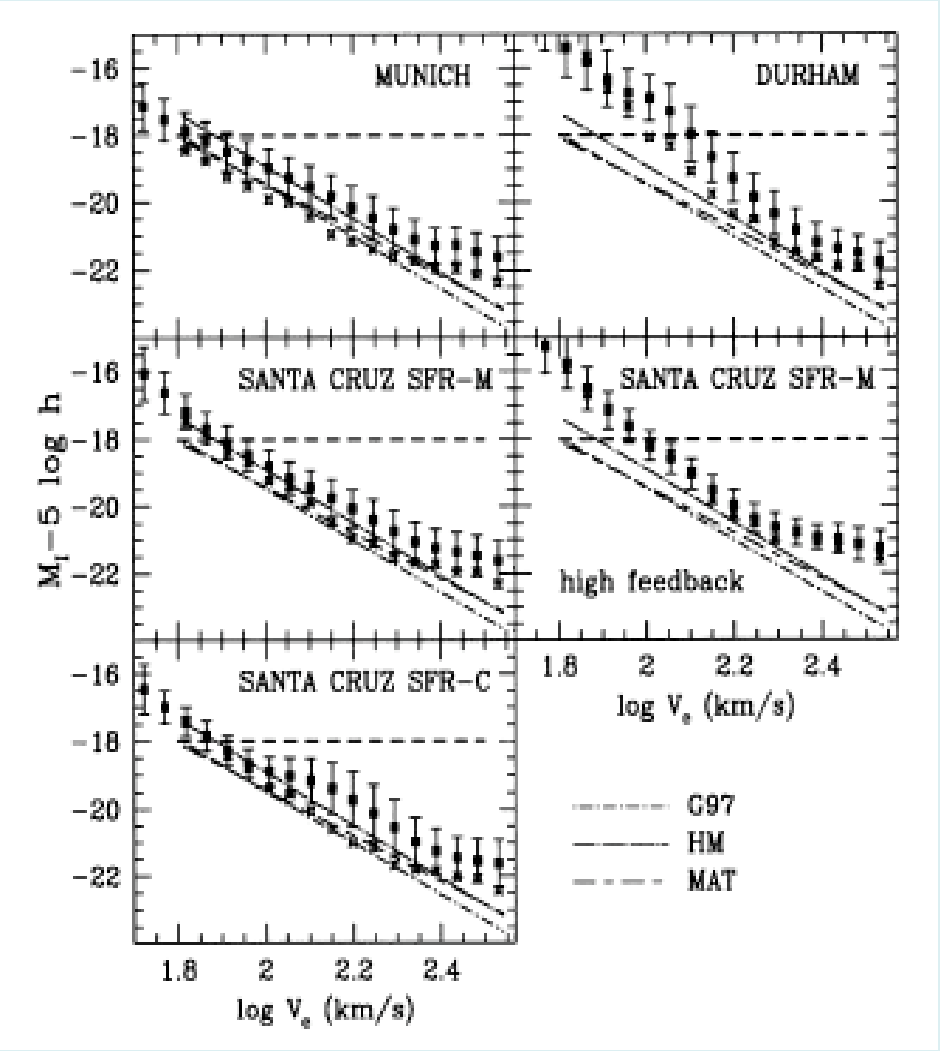
Normalization

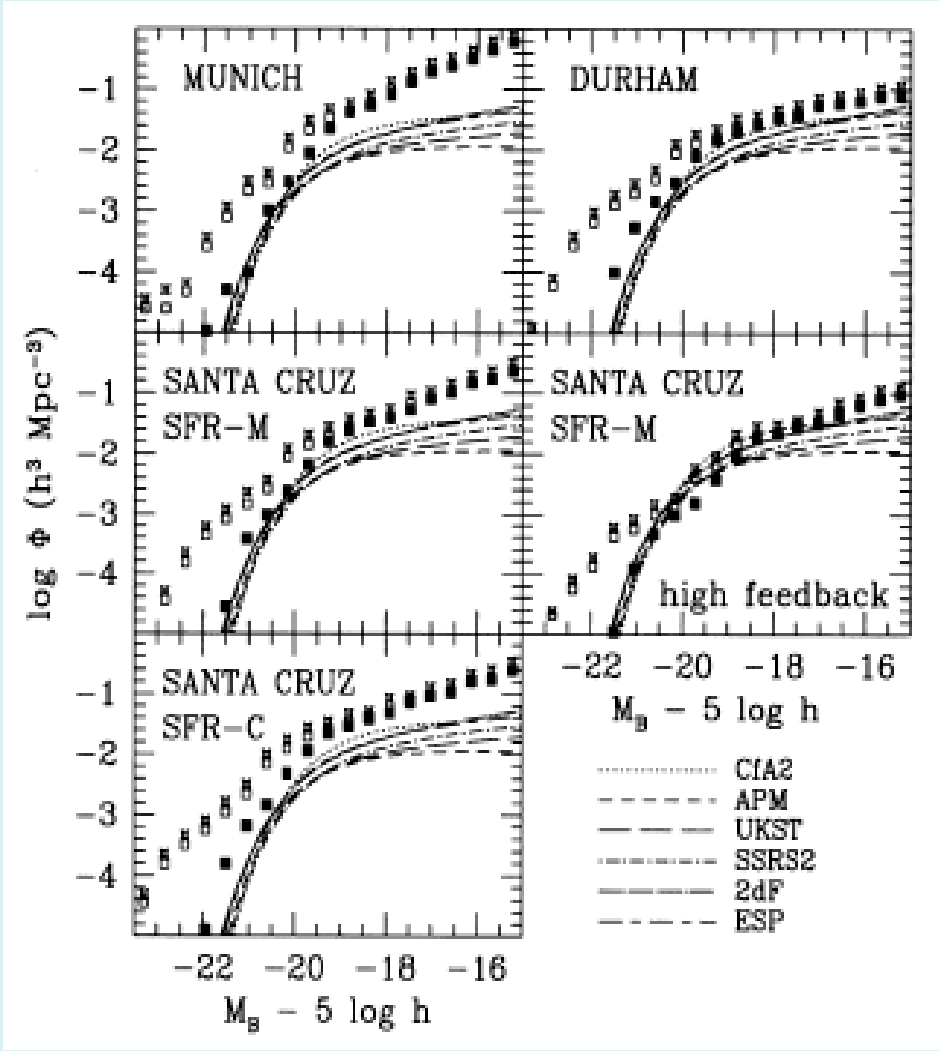
- Two ways:
  - Fitting luminosity density of the Universe
  - Fitting properties of the Milky-Way or Tully-Fisher relation
- Offset Tully-Fisher or Missing Satellite problem





Normalization (2)

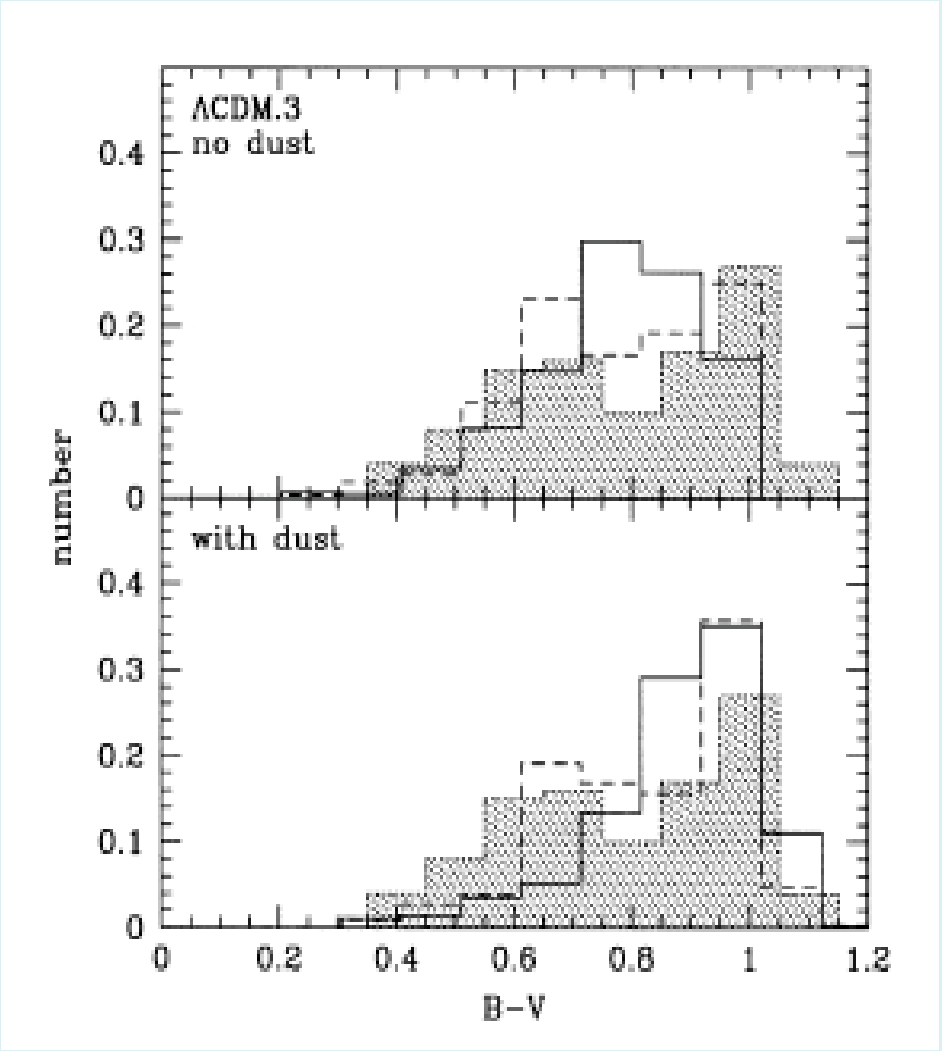




Successes & Problems

They follow certain sets of observations reasonably, but:

- Too few red gelaxies (SM black holes, gas cooling?)
- Missing Satellite (and Tully-Fisher) problem



Is semi-analytical modelling useful?

- Too many free parameters
  - differs between models also, is more better?
- Not able to be predictive
- Results doubtful
- Observations to be trusted?
- But: maybe able to get more insight in which physical processes are dominant by trying to fit to the “right” results?